example, Lavoisier (1789) himself characterized fermentation as involving the oxygenation of carbon in sugar to produce carbon dioxide at the expense of the deoxygenation of the remainder, yielding alcohol. Shortly thereafter Louis Jacques Thénard (1803) and subsequently Joseph Louis Gay-Lussac (1810) worked out the general formula for fermentation, represented in modern notation as

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH.$$

At the time yeast was not regarded as an organism, so fermentation, although involving organic compounds, was regarded as a strictly chemical process. In further research in collaboration with Pierre Simon LaPlace, Lavoisier measured the heat generated as animals respired and compared that with the heat of combustion of coal that generated the same amount of carbon dioxide. They concluded, "Respiration is thus a very slow combustion phenomenon, very similar to that of coal" (Lavoisier & LaPlace, 1780, p. 331 in 1886 reprint).

In the succeeding decades, a host of chemists turned their attention to the phenomena exhibited by living systems. One of the challenges they confronted is that chemical reactions occur in living organisms that do not freely occur outside of them. In some cases chemists identified and isolated substances that promoted reactions without being consumed in them. Gottlieb Sigismund Kirchhoff (1816) had shown that germinating grains of malt facilitated the conversion of starch to sugar. Payen and Persoz (1833) later extracted the chemical component that facilitated the process and named it *diastase*. Jöns Jacob Berzelius (1836) introduced the term *catalysis* for the process and, appealing to inorganic examples, proposed to apply the idea to fermentation.

> This property was not an isolated, exceptional behaviour but proved to be a more general one, exhibited by substances to varying extents. . . . We have found, for instance, that the conversion of sugar to carbon dioxide and alcohol, which occurs in fermentation through the influence of an insoluble substance known by the name of ferment . . . could not be explained by a chemical reaction between sugar and ferment resembling double decomposition. However, when compared with phenomena known in inorganic Nature, the preceding phenomenon most

Antoine François de Fourcroy concluded that substances such as oils, acids, mucilages, and fibres "differ from each other only in the number and the proportions in which the primary substances are combined in them" (Fourcroy, 1789, translation by Holmes, 1963, p. 57). One consequence of this research was the determination that nitrogen was present in far higher concentrations in animal tissue than plant tissue, inspiring the hypothesis that plant tissue had to be animalized by increasing the concentration of nitrogen to generate animal tissue.